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CORRELATION OF HELICOPTER NOISE LEVELS WITH PHYSICAL AND PERFOR--ETC(U)
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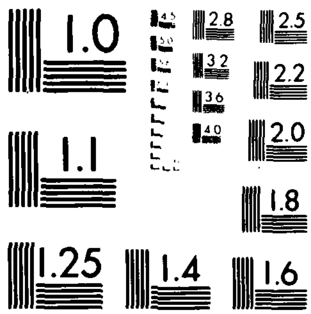
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LEVEL II (12)

U.S. Department of Transportation
Federal Aviation Administration

# Correlations of Helicopter Noise Levels with Physical and Performance Characteristics

Office of Environment And Energy
Washington, D.C. 20591

## A Preliminary Report







FAA-EE-80-42

September 1980

By J. Steven Newman

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16. Abstract

This report investigates the correlation between physical and performance characteristics of helicopters and the noise levels which they generate in various operational modes. The analysis is generally empirical although several theoretical functions described in the literature have been examined. The EPNL is the acoustical metric employed in this study. One, two, and three-step multiple regression analyses are conducted for takeoff, approach, and level flyover operations. Plots are provided for the three best single variable regression models for each mode of flight.

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## 1.0 INTRODUCTION

This report investigates the correlation between physical and performance characteristics of helicopters and the noise levels which the helicopters generate in various operational modes. The analysis is generally empirical although several theoretical functions described in the technical literature have been examined. The Effective Perceived Noise Level (EPNL) is the acoustical metric employed in this study. It is anticipated that subsequent analyses will examine trends for other metrics, in particular the Noise Exposure Level (single event, integrated A-Weighted Sound Level). This report has been limited to presenting statistical analyses. Parameters are tested for correlation with EPNL, a single event cumulative energy noise metric. The units of most analysis parameters are not energy. However, a limited number of variables dimensionally consistent with power, intensity or energy are tested.

### 1.1 Input Data Files

This study utilizes a data file assembled for analyses conducted in FAA-AEE-79-3, "Noise Levels and Flight Profiles of Eight Helicopters Using Proposed International Certification Procedures (Newman, J. S., Rickley, E. J.). This data file (Table 1.1) has been expanded to include a variety of physical parameters which may be expected to influence resulting noise levels. The legend for Table 1 is presented below:

NOTE: $V_H$ is the speed at maximum continuous power.
$V_{NE}$ is the never exceed speed.

# LEGEND FOR CROSS CORRELATION MATRIX

| | | |
|---|---|---|
| TYPE | - | Helicopter designation |
| EPNL | - | Effective Perceived Noise Level, (level flyover) expressed in decibels |
| WEIGHT | - | Test weight, lbs. |
| AREA | - | Total main rotor blade area (square feet) |
| MACH | - | Mach number of advancing blade; sum .9 (lesser of $V_H$ or $V_{NE}$) level flyover forward speed and rotational tip speed |
| SHP | - | Maximum engine shaft horsepower |
| M-DISC | - | Main disc area, square feet |
| BRC | - | Best rate of climb, feet/minute |
| M-FREQ | - | Main rotor blade frequency. Using main rotor rpm (Jane's) and number of blades (Jane's) units in Blade Passages/Sec. |
| T-BLADE | - | Total tail rotor blade area (square feet) |
| EPNLA | - | Effective Perceived Noise Level (approach), decibels |
| LOGW | - | Common logarithm of weight |
| LOGA | - | Common logarithm of area |
| LOGS | - | Common logarithm of shaft horsepower |
| LOGMD | - | Common logarithm of main disc area |
| DISPLO | - | Main disc loading, lbs/square feet |
| LOGTB | - | Common logarithm of total tail blade area |
| MACH6 | - | Mach number to sixth power |
| TSPEED | - | Rotational tip speed of tail rotor (feet/second) |
| MSPEED | - | Main rotor rotational tip speed (feet/second) |
| T-MACH | - | Tail rotor, rotational tip mach number |
| F1 | - | $\log_{10}((\text{T-MACH} \times \text{Weight})^2/\text{T-Blade})$ |

F2 - $\text{Log}_{10}$ ((MACH x Weight)$^2$/AREA)

F3 - $\text{Log}_{10}$ (SHP x M-DISC/MACH)

F4 - $\text{Log}_{10}$ (MACH$^6$ x T-BLADE)

F5 - $\text{Log}_{10}$ (T-MACH$^6$ x AREA)

## 2.0 CROSS CORRELATION OF ANALYSIS PARAMETERS

This section examines and discusses the interdependence between the parameters used in the regression analyses.

### 2.1 Cross Correlation Matrix

The matrix displayed as Table 2.1 (four pages) provides insight into the interrelationships between test variables and the relationship of each variable to EPNL for takeoff, approach and level flyover. Each entry in the matrix includes the correlation coefficient "R," the probability that the observed correlation is due merely to chance, and the number of observations. Many of the variables correlate equally well with the acoustical measures for all operational modes. Therefore, it is possible to develop a large number of single variable regression models which predict noise with similar accuracy.

The "good predictor" family of parameters includes:

- Weight: Helicopter Weight
- Area: Main Rotor Area
- SHP: Shaft Horsepower
- MDISC: Main Rotor Disc Area
- LOGW: Log Weight
- LOGA: Log Area

## 1.1 INPUT DATA FILES

### HELICOPTER NOISE REGRESSION ANALYSIS

| OBS | TYPE | EPNL | WEIGHT | AREA | MSPEED | SHP | M DISC | BRC | M FREQ | T BLADE | EPNLA | EPNLT | TSPEED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | SA330J | 91.4 | 15,532 | 188 | 682 | 3,150 | 1,925 | 1,400 | 17.6 | 15.0 | 95.6 | 95.4 | 669 |
| 2 | BO105 | 88.4 | 5,070 | 116 | 724 | 840 | 804 | 1,772 | 20.5 | 3.7 | 91.7 | 89.1 | 730 |
| 3 | B206L | 85.8 | 4,000 | 37 | 763 | 840 | 1,075 | 1,550 | 13.1 | 2.2 | 90.3 | 85.9 | 691 |
| 4 | S61 | 92.6 | 22,050 | 232 | 659 | 2,800 | 3,019 | 2,200 | 16.9 | 12.1 | 94.0 | 95.9 | 630 |
| 5 | S65 | 97.1 | 37,000 | 475 | 700 | 7,925 | 4,070 | 2,180 | 18.5 | 19.2 | 99.9 | 95.7 | 663 |
| 6 | B212 | 94.6 | 10,500 | 82 | 817 | 1,800 | 1,809 | 1,420 | 10.8 | 8.1 | 95.7 | 91.7 | 740 |
| 7 | H500C | 85.8 | 2,550 | 29 | 667 | 400 | 547 | 1,700 | 32.3 | 1.7 | 87.7 | 85.1 | 692 |
| 8 | SA341G | 86.1 | 3,970 | 51 | 681 | 590 | 931 | 1,770 | 18.9 | 1.9 | 89.5 | 89.5 | 696 |
| 9 | SA350 | 87.2 | 4,180 | 47 | 671 | 641 | 962 | 1,575 | 18.3 | 3.7 | 91.2 | 89.2 | 653 |
| 10 | SA321F | 92.0 | 25,300 | 298 | 688 | 4,650 | 3,058 | 1,312 | 21.2 | 29.5 | 98.6 | 98.4 | 351 |
| 11 | A109 | 90.4 | 5,390 | 80 | 727 | 840 | 1,023 | 1,620 | 25.7 | 4.4 | 93.0 | - | 728 |
| 12 | MI6A | 103.4 | 88,440 | 942 | 721 | 11,000 | 10,386 | 1,476 | 10.0 | 64.9 | 107.4 | - | 733 |
| 13 | MI2 | 89.5 | 7,755 | 94 | 623 | 900 | 1,772 | 1,320 | 12.4 | 6.5 | 96.1 | - | 631 |
| 14 | MI8 | 97.3 | 25,212 | 298 | 702 | 3,000 | 3,848 | 1,102 | 16.0 | 16.0 | 99.6 | - | 732 |
| 15 | WG-13 | 97.7 | 9,350 | 109 | 699 | 1,500 | 1,385 | 1,200 | 21.2 | 8.6 | 96.9 | 91.6 | 717 |
| 16 | B47G | 90.3 | 2,728 | 33 | 720 | 220 | 1,075 | 800 | 12.4 | 2.4 | 89.6 | - | 659 |
| 17 | H300C | 80.6 | 1,804 | 23 | 665 | 190 | 566 | 750 | 23.7 | 1.7 | - | - | 689 |
| 18 | S64 | 96.7 | 42,812 | 518 | 700 | 9,000 | 4,070 | 1,330 | 18.6 | 20.2 | 98.6 | - | 702 |
| 19 | SA365C | 89.4 | 7,480 | 83 | 689 | 1,300 | 1,116 | 1,968 | 23.3 | 9.8 | 94.0 | - | 725 |

## 1.1 INPUT DATA FILES (Continued)

### HELICOPTER NOISE REGRESSION ANALYSIS

| OBS | TYPE | LOGW | LOGA | LOGTB | LOGS | LOGMD | DISLO | MACH | MACH6 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | SA330J | 4.19 | 2.27 | 1.18 | 3.50 | 3.28 | 8.07 | 0.80 | 0.26 |
| 2 | BO105 | 3.71 | 2.06 | 0.57 | 2.92 | 2.91 | 6.31 | 0.83 | 0.32 |
| 3 | B206L | 3.60 | 1.57 | 0.34 | 2.92 | 3.03 | 3.72 | 0.86 | 0.41 |
| 4 | S61 | 4.34 | 2.37 | 1.08 | 3.45 | 3.48 | 7.30 | 0.79 | 0.24 |
| 5 | S65 | 4.57 | 2.68 | 1.28 | 3.90 | 3.61 | 9.09 | 0.82 | 0.31 |
| 6 | B212 | 4.02 | 1.91 | 0.91 | 3.26 | 3.26 | 5.80 | 0.87 | 0.45 |
| 7 | H500C | 3.41 | 1.46 | 0.23 | 2.60 | 2.74 | 4.67 | 0.78 | 0.22 |
| 8 | SA341G | 3.60 | 1.71 | 0.28 | 2.77 | 2.97 | 4.26 | 0.80 | 0.27 |
| 9 | SA350 | 3.62 | 1.67 | 0.57 | 2.81 | 2.98 | 4.35 | 0.77 | 0.21 |
| 10 | SA321F | 4.40 | 2.47 | 1.47 | 3.67 | 3.49 | 8.27 | 0.79 | 0.25 |
| 11 | A109 | 3.73 | 1.90 | 0.64 | 2.92 | 3.01 | 5.27 | 0.85 | 0.37 |
| 12 | MI6A | 4.95 | 2.97 | 1.81 | 4.04 | 4.02 | 8.52 | 0.83 | 0.32 |
| 13 | MI2 | 3.89 | 1.97 | 0.81 | 2.95 | 3.25 | 4.38 | 0.67 | 0.09 |
| 14 | MI8 | 4.40 | 2.47 | 1.20 | 3.48 | 3.59 | 6.56 | 0.79 | 0.25 |
| 15 | WG-13 | 3.97 | 2.04 | 0.93 | 3.18 | 3.14 | 6.75 | 0.82 | 0.31 |
| 16 | B47G | 3.44 | 1.52 | 0.38 | 2.34 | 3.03 | 2.54 | 0.77 | 0.21 |
| 17 | H300C | 3.26 | 1.36 | 0.23 | 2.28 | 2.75 | 3.19 | 0.72 | 0.14 |
| 18 | S64 | 4.63 | 2.71 | 1.31 | 3.95 | 3.61 | 10.52 | 0.78 | 0.22 |
| 19 | SA365C | 3.87 | 1.92 | 0.99 | 3.11 | 3.05 | 6.70 | 0.80 | 0.27 |

## 1.1 INPUT DATA FILES (Concluded)

## HELICOPTER NOISE REGRESSION ANALYSIS

| OBS | TYPE | F1 | F2 | F3 | F4 | F5 |
|---|---|---|---|---|---|---|
| 1 | SA330J | 6.76189 | 5.91467 | 6.87955 | 1.69328 | 0.94073 |
| 2 | BO105 | 6.47313 | 5.18251 | 5.91106 | 1.57532 | 0.95841 |
| 3 | B206L | 6.44533 | 5.50604 | 6.02063 | 1.17856 | 0.31908 |
| 4 | S61 | 7.10738 | 6.11200 | 7.03169 | 1.73750 | 0.87555 |
| 5 | S65 | 7.40080 | 6.29196 | 7.59247 | 2.17344 | 1.31979 |
| 6 | B212 | 6.77703 | 6.01214 | 6.57093 | 1.56453 | 0.84322 |
| 7 | H500C | 6.16752 | 5.13039 | 5.45019 | 0.80152 | 0.21705 |
| 8 | SA341G | 6.50872 | 5.30027 | 5.83467 | 1.13834 | 0.47724 |
| 9 | SA350 | 6.20865 | 5.34392 | 5.90320 | 0.99310 | 0.27559 |
| 10 | SA321F | 6.33170 | 6.13156 | 7.25312 | 1.87283 | -0.53993 |
| 11 | A109 | 6.44866 | 5.41562 | 6.00639 | 1.46970 | 0.78989 |
| 12 | MI6A | 7.71593 | 6.75620 | 8.13936 | 2.48492 | 1.87869 |
| 13 | MI2 | 6.47098 | 5.45619 | 6.37763 | 0.92358 | 0.48732 |
| 14 | MI8 | 7.23279 | 6.12854 | 7.16259 | 1.87283 | 1.37530 |
| 15 | WG-13 | 6.62283 | 5.73361 | 6.40284 | 1.52566 | 0.88456 |
| 16 | B47G | 6.03392 | 5.12583 | 5.48750 | 0.83649 | 0.14584 |
| 17 | H300C | 5.86313 | 4.86593 | 5.17393 | 0.50728 | 0.10506 |
| 18 | S64 | 7.55513 | 6.32951 | 7.67348 | 2.05646 | 1.50637 |
| 19 | SA365C | 6.38192 | 5.63898 | 6.25648 | 1.34985 | 0.79512 |

TABLE 2.1

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

| | EPNL | WEIGHT | AREA | MSPEED | SHP | M_DISC | BRC | M_FREQ | T_BLADE | EPNLA | EPNLT | TSPEED | LOGW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EPNL | 1.00000 | 0.79053 | 0.79117 | 0.25695 | 0.77085 | 0.79268 | 0.08050 | -0.43628 | 0.74421 | 0.91138 | 0.67551 | 0.09015 | 0.87708 |
| | 0.0000 | 0.0001 | 0.0001 | 0.2883 | 0.0001 | 0.0001 | 0.7432 | 0.0618 | 0.0003 | 0.0001 | 0.0225 | 0.7136 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| WEIGHT | 0.79053 | 1.00000 | 0.99371 | 0.07690 | 0.94703 | 0.98737 | 0.10075 | -0.39223 | 0.95648 | 0.87924 | 0.84780 | -0.01080 | 0.87139 |
| | 0.0001 | 0.0000 | 0.0001 | 0.7544 | 0.0001 | 0.0001 | 0.6815 | 0.0967 | 0.0001 | 0.0001 | 0.0010 | 0.9650 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| AREA | 0.79117 | 0.99371 | 1.00000 | 0.05399 | 0.96552 | 0.97105 | 0.12136 | -0.34309 | 0.93830 | 0.88024 | 0.80291 | -0.02204 | 0.88408 |
| | 0.0001 | 0.0001 | 0.0000 | 0.8262 | 0.0001 | 0.0001 | 0.6206 | 0.1504 | 0.0001 | 0.0001 | 0.0029 | 0.9286 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| MSPEED | 0.25695 | 0.07690 | 0.05399 | 1.00000 | 0.07931 | 0.08655 | -0.05065 | -0.28462 | 0.06807 | 0.05264 | -0.19970 | 0.31234 | 0.06854 |
| | 0.2883 | 0.7544 | 0.8262 | 0.0000 | 0.7469 | 0.7246 | 0.8369 | 0.2376 | 0.7819 | 0.8357 | 0.5560 | 0.1930 | 0.7804 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| SHP | 0.77085 | 0.94703 | 0.96552 | 0.07931 | 1.00000 | 0.89368 | 0.15580 | -0.31874 | 0.86709 | 0.84641 | 0.76887 | -0.08031 | 0.89840 |
| | 0.0001 | 0.0001 | 0.0001 | 0.7469 | 0.0000 | 0.0001 | 0.5242 | 0.1835 | 0.0001 | 0.0001 | 0.0057 | 0.7438 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| M_DISC | 0.79268 | 0.98737 | 0.97105 | 0.08655 | 0.89368 | 1.00000 | 0.06522 | -0.46733 | 0.95913 | 0.88209 | 0.85679 | -0.00042 | 0.84931 |
| | 0.0001 | 0.0001 | 0.0001 | 0.7246 | 0.0001 | 0.0000 | 0.7908 | 0.0436 | 0.0001 | 0.0001 | 0.0008 | 0.9986 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| BRC | 0.08050 | 0.10075 | 0.12136 | -0.05065 | 0.15580 | 0.06522 | 1.00000 | 0.21970 | 0.03589 | -0.09928 | 0.08042 | 0.06069 | 0.23246 |
| | 0.7432 | 0.6815 | 0.6206 | 0.8369 | 0.5242 | 0.7908 | 0.0000 | 0.3661 | 0.8840 | 0.6951 | 0.8142 | 0.8051 | 0.3382 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| M_FREQ | -0.43628 | -0.39223 | -0.34309 | -0.28462 | -0.31874 | -0.46733 | 0.21970 | 1.00000 | -0.36992 | -0.41936 | -0.28833 | -0.00522 | -0.39572 |
| | 0.0618 | 0.0967 | 0.1504 | 0.2376 | 0.1835 | 0.0436 | 0.3661 | 0.0000 | 0.1190 | 0.0832 | 0.3899 | 0.9831 | 0.0935 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| T_BLADE | 0.74421 | 0.95648 | 0.93830 | 0.06807 | 0.86709 | 0.95913 | 0.03589 | -0.36992 | 1.00000 | 0.88060 | 0.90556 | -0.16209 | 0.82817 |
| | 0.0003 | 0.0001 | 0.0001 | 0.7819 | 0.0001 | 0.0001 | 0.8840 | 0.1190 | 0.0000 | 0.0001 | 0.0001 | 0.5074 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| EPNLA | 0.91138 | 0.87924 | 0.88024 | 0.05264 | 0.84641 | 0.88209 | -0.09928 | -0.41936 | 0.88060 | 1.00000 | 0.85292 | -0.07047 | 0.93104 |
| | 0.0001 | 0.0001 | 0.0001 | 0.8357 | 0.0001 | 0.0001 | 0.6951 | 0.0832 | 0.0001 | 0.0000 | 0.0008 | 0.7811 | 0.0001 |
| | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 11 | 18 | 18 |
| EPNLT | 0.67551 | 0.84780 | 0.80291 | -0.19970 | 0.76887 | 0.85679 | 0.08042 | -0.28833 | 0.90556 | 0.85292 | 1.00000 | -0.60426 | 0.94381 |
| | 0.0225 | 0.0010 | 0.0029 | 0.5560 | 0.0057 | 0.0008 | 0.8142 | 0.3899 | 0.0001 | 0.0008 | 0.0000 | 0.0490 | 0.0001 |
| | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| TSPEED | 0.09015 | -0.01080 | -0.02204 | 0.31234 | -0.08031 | -0.00042 | 0.06069 | -0.00522 | -0.16209 | -0.07047 | -0.60426 | 1.00000 | -0.14994 |
| | 0.7136 | 0.9650 | 0.9286 | 0.1930 | 0.7438 | 0.9986 | 0.8051 | 0.9831 | 0.5074 | 0.7811 | 0.0490 | 0.0000 | 0.5401 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| LOGW | 0.87708 | 0.87139 | 0.88408 | 0.06854 | 0.89840 | 0.84931 | 0.23246 | -0.39572 | 0.82817 | 0.93104 | 0.94381 | -0.14994 | 1.00000 |
| | 0.0001 | 0.0001 | 0.0001 | 0.7804 | 0.0001 | 0.0001 | 0.3382 | 0.0935 | 0.0001 | 0.0001 | 0.0001 | 0.5401 | 0.0000 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |

TABLE 2.1 (Continued)

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

| | LOGA | LOGTB | LOGS | LOGMD | DISLO | MACH | TMACH | MACH6 | F1 | F2 | F | F4 | F5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EPNL | 0.85276 | 0.85340 | 0.82731 | 0.87489 | 0.72512 | 0.33729 | 0.09015 | 0.30776 | 0.84583 | 0.88044 | 0.86046 | 0.86563 | 0.77495 |
| | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0004 | 0.1579 | 0.7136 | 0.1999 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| WEIGHT | 0.85554 | 0.82667 | 0.81266 | 0.89622 | 0.70275 | 0.16211 | -0.01080 | 0.12237 | 0.83365 | 0.84928 | 0.86558 | 0.81561 | 0.67820 |
| | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0008 | 0.5073 | 0.9650 | 0.6177 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0014 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| AREA | 0.89427 | 0.83270 | 0.83315 | 0.89637 | 0.74307 | 0.15438 | -0.02204 | 0.10794 | 0.84829 | 0.84584 | 0.87861 | 0.83862 | 0.67488 |
| | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0003 | 0.5280 | 0.9286 | 0.6600 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0015 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| MSPEED | 0.01717 | 0.03924 | 0.11961 | 0.08541 | 0.01727 | 0.82387 | 0.31234 | 0.87711 | 0.15912 | 0.19667 | 0.08299 | 0.26621 | 0.23625 |
| | 0.9444 | 0.8733 | 0.6257 | 0.7281 | 0.9440 | 0.0001 | 0.1930 | 0.0001 | 0.5153 | 0.4197 | 0.7355 | 0.2706 | 0.3302 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| SHP | 0.88990 | 0.83566 | 0.88327 | 0.88437 | 0.82687 | 0.17251 | -0.08031 | 0.12451 | 0.85673 | 0.86918 | 0.90433 | 0.84945 | 0.63452 |
| | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.4800 | 0.7438 | 0.6115 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0035 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| M_DISC | 0.82507 | 0.81062 | 0.77031 | 0.90113 | 0.61882 | 0.14875 | -0.00042 | 0.12152 | 0.81099 | 0.83452 | 0.84173 | 0.78287 | 0.67330 |
| | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0047 | 0.5433 | 0.9986 | 0.6202 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0016 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| BRC | 0.24999 | 0.14655 | 0.32369 | 0.11520 | 0.34516 | 0.34802 | 0.06069 | 0.31324 | 0.31043 | 0.23907 | 0.23710 | 0.33174 | 0.18344 |
| | 0.3020 | 0.5494 | 0.1764 | 0.6386 | 0.1478 | 0.1443 | 0.8051 | 0.1916 | 0.1958 | 0.3243 | 0.3284 | 0.1653 | 0.4522 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| M_FREQ | -0.28834 | -0.36277 | -0.31353 | -0.56503 | -0.02767 | -0.03070 | -0.00522 | -0.11339 | -0.40076 | -0.47037 | -0.42490 | -0.26119 | -0.32912 |
| | 0.2312 | 0.1269 | 0.1912 | 0.0117 | 0.9105 | 0.9007 | 0.9831 | 0.6439 | 0.0891 | 0.0421 | 0.0698 | 0.2801 | 0.1689 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| T_BLADE | 0.80852 | 0.84837 | 0.76764 | 0.85189 | 0.65043 | 0.16482 | -0.16209 | 0.12653 | 0.69194 | 0.81245 | 0.81943 | 0.77375 | 0.56792 |
| | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0026 | 0.5001 | 0.5074 | 0.6057 | 0.0010 | 0.0001 | 0.0001 | 0.0001 | 0.0112 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| EPNLA | 0.91026 | 0.94305 | 0.88246 | 0.92922 | 0.73837 | 0.06959 | -0.07047 | 0.07347 | 0.80155 | 0.90649 | 0.92477 | 0.84568 | 0.69888 |
| | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0005 | 0.7838 | 0.7811 | 0.7720 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0013 |
| | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| EPNLT | 0.92220 | 0.95400 | 0.90912 | 0.90917 | 0.88556 | -0.13522 | -0.60426 | -0.16689 | 0.57894 | 0.86743 | 0.92252 | 0.86066 | 0.19134 |
| | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0003 | 0.6918 | 0.0490 | 0.6238 | 0.0620 | 0.0005 | 0.0001 | 0.0007 | 0.5730 |
| | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| TSPEED | -0.14272 | -0.23415 | -0.15392 | -0.15240 | -0.14511 | 0.26467 | 1.00000 | 0.29416 | 0.20866 | -0.12001 | -0.16626 | -0.04759 | 0.58925 |
| | 0.5600 | 0.3346 | 0.5293 | 0.5334 | 0.5534 | 0.2735 | 0.0000 | 0.2215 | 0.3913 | 0.6246 | 0.4963 | 0.8466 | 0.0079 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| LOGW | 0.98145 | 0.96313 | 0.97745 | 0.96936 | 0.88872 | 0.21242 | -0.14994 | 0.17339 | 0.90740 | 0.97752 | 0.99640 | 0.94254 | 0.68491 |
| | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.3826 | 0.5401 | 0.4778 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0012 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |

TABLE 2.1 (Continued)

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

| | EPNL | WEIGHT | AREA | MSPEED | SHP | M_DISC | BRC | M_FREQ | T_BLADE | EPNLA | EPNLT | TSPEED | LOGW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LOGA | 0.85276 | 0.85554 | 0.88427 | 0.01717 | 0.88990 | 0.82507 | 0.24999 | -0.28834 | 0.80852 | 0.91026 | 0.92220 | -0.14272 | 0.98145 |
| | 0.0001 | 0.0001 | 0.0001 | 0.9444 | 0.0001 | 0.0001 | 0.3020 | 0.2312 | 0.0001 | 0.0001 | 0.0001 | 0.5600 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| LOGTB | 0.85340 | 0.82667 | 0.83270 | 0.03924 | 0.83566 | 0.81062 | 0.14655 | -0.36277 | 0.84837 | 0.94305 | 0.95400 | -0.23415 | 0.96313 |
| | 0.0001 | 0.0001 | 0.0001 | 0.8733 | 0.0001 | 0.0001 | 0.5494 | 0.1269 | 0.0001 | 0.0001 | 0.0001 | 0.3346 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| LOGS | 0.82731 | 0.81266 | 0.83315 | 0.11961 | 0.88327 | 0.77031 | 0.32369 | -0.31353 | 0.76764 | 0.98246 | 0.90912 | -0.15392 | 0.97745 |
| | 0.0001 | 0.0001 | 0.0001 | 0.6257 | 0.0001 | 0.0001 | 0.1764 | 0.1912 | 0.0001 | 0.0001 | 0.0001 | 0.5293 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| LOGMD | 0.87489 | 0.89622 | 0.89637 | 0.08541 | 0.88437 | 0.90113 | 0.11520 | -0.56503 | 0.85189 | 0.92922 | 0.90917 | -0.15240 | 0.96936 |
| | 0.0001 | 0.0001 | 0.0001 | 0.7281 | 0.0001 | 0.0001 | 0.6386 | 0.0117 | 0.0001 | 0.0001 | 0.0001 | 0.5334 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| DISLO | 0.72512 | 0.70275 | 0.74307 | 0.01727 | 0.82687 | 0.61882 | 0.34516 | -0.02767 | 0.65043 | 0.73837 | 0.88556 | -0.14511 | 0.88872 |
| | 0.0004 | 0.0008 | 0.0003 | 0.9440 | 0.0001 | 0.0047 | 0.1478 | 0.9105 | 0.0026 | 0.0005 | 0.0003 | 0.5534 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| MACH | 0.33729 | 0.16211 | 0.15438 | 0.82387 | 0.17251 | 0.14875 | 0.34802 | -0.03070 | 0.16482 | 0.06959 | -0.13522 | 0.26467 | 0.21242 |
| | 0.1579 | 0.5073 | 0.5280 | 0.0001 | 0.4800 | 0.5433 | 0.1443 | 0.9007 | 0.5001 | 0.7838 | 0.6918 | 0.2735 | 0.3826 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| TMACH | 0.09015 | -0.01080 | -0.02204 | 0.31234 | -0.08031 | -0.00042 | 0.06069 | -0.00522 | -0.16209 | -0.07047 | -0.60426 | 1.00000 | -0.14994 |
| | 0.7136 | 0.9650 | 0.9286 | 0.1930 | 0.7438 | 0.9986 | 0.8051 | 0.9831 | 0.5074 | 0.7811 | 0.0490 | 0.0000 | 0.5401 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| MACH6 | 0.30776 | 0.12237 | 0.10794 | 0.87711 | 0.12451 | 0.12152 | 0.31324 | -0.11339 | 0.12653 | 0.07347 | -0.16689 | 0.29416 | 0.17339 |
| | 0.1999 | 0.6177 | 0.6600 | 0.0001 | 0.6115 | 0.6202 | 0.1916 | 0.6439 | 0.6057 | 0.7720 | 0.6238 | 0.2215 | 0.4778 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| F1 | 0.84583 | 0.83365 | 0.84829 | 0.15912 | 0.85673 | 0.81099 | 0.31043 | -0.40076 | 0.69194 | 0.80155 | 0.57894 | 0.20866 | 0.90740 |
| | 0.0001 | 0.0001 | 0.0001 | 0.5153 | 0.0001 | 0.0001 | 0.1958 | 0.0891 | 0.0010 | 0.0001 | 0.0620 | 0.3913 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| F2 | 0.88044 | 0.84928 | 0.84584 | 0.19667 | 0.86918 | 0.83452 | 0.23907 | -0.47037 | 0.81245 | 0.90649 | 0.86743 | -0.12001 | 0.97752 |
| | 0.0001 | 0.0001 | 0.0001 | 0.4197 | 0.0001 | 0.0001 | 0.3243 | 0.0421 | 0.0001 | 0.0001 | 0.0005 | 0.6246 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| F3 | 0.86046 | 0.86558 | 0.87861 | 0.08299 | 0.90433 | 0.84173 | 0.23710 | -0.42490 | 0.81943 | 0.92477 | 0.92252 | -0.16626 | 0.99640 |
| | 0.0001 | 0.0001 | 0.0001 | 0.7355 | 0.0001 | 0.0001 | 0.3284 | 0.0698 | 0.0001 | 0.0001 | 0.0001 | 0.4963 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| F4 | 0.86563 | 0.81501 | 0.83862 | 0.26621 | 0.84945 | 0.78287 | 0.33174 | -0.26119 | 0.77375 | 0.86568 | 0.86066 | -0.04759 | 0.94254 |
| | 0.0001 | 0.0001 | 0.0001 | 0.2706 | 0.0001 | 0.0001 | 0.1653 | 0.2801 | 0.0001 | 0.0001 | 0.0007 | 0.8466 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |
| F5 | 0.77495 | 0.67820 | 0.67488 | 0.23625 | 0.63452 | 0.67330 | 0.18344 | -0.32912 | 0.56792 | 0.69888 | 0.19134 | 0.58925 | 0.68491 |
| | 0.0001 | 0.0014 | 0.0015 | 0.3302 | 0.0035 | 0.0016 | 0.4522 | 0.1689 | 0.0112 | 0.0013 | 0.5730 | 0.0079 | 0.0012 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 11 | 19 | 19 |

TABLE 2.1 (Concluded)

CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

| | LOGA | LOGTB | LOGS | LOGMD | DISLO | MACH | TMACH | MACH6 | F1 | F2 | F3 | F4 | F5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LOGA | 1.00000 | 0.94396 | 0.95947 | 0.93423 | 0.90700 | 0.18976 | -0.14272 | 0.13980 | 0.89238 | 0.92411 | 0.97157 | 0.95266 | 0.67297 |
| | 0.0000 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.4365 | 0.5600 | 0.5681 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0016 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| LOGTB | 0.94396 | 1.00000 | 0.93472 | 0.92546 | 0.86439 | 0.16785 | -0.23415 | 0.12995 | 0.78322 | 0.93881 | 0.95335 | 0.89529 | 0.64393 |
| | 0.0001 | 0.0000 | 0.0001 | 0.0001 | 0.0001 | 0.4922 | 0.3346 | 0.5960 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0029 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| LOGS | 0.95947 | 0.93472 | 1.00000 | 0.91059 | 0.93432 | 0.30681 | -0.15392 | 0.26795 | 0.88978 | 0.96577 | 0.98347 | 0.95200 | 0.65489 |
| | 0.0001 | 0.0001 | 0.0000 | 0.0001 | 0.0001 | 0.2014 | 0.5293 | 0.2674 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0023 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| LOGMD | 0.93423 | 0.92546 | 0.91059 | 1.00000 | 0.75781 | 0.14802 | -0.15240 | 0.12578 | 0.88673 | 0.95682 | 0.96942 | 0.87958 | 0.65673 |
| | 0.0001 | 0.0001 | 0.0001 | 0.0000 | 0.0002 | 0.5453 | 0.5334 | 0.6079 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0023 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| DISLO | 0.90700 | 0.86439 | 0.93432 | 0.75781 | 1.00000 | 0.25297 | -0.14511 | 0.17839 | 0.79363 | 0.84466 | 0.88183 | 0.89103 | 0.60045 |
| | 0.0001 | 0.0001 | 0.0001 | 0.0002 | 0.0000 | 0.2961 | 0.5534 | 0.4650 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0066 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| MACH | 0.18976 | 0.16785 | 0.30681 | 0.14802 | 0.25297 | 1.00000 | 0.26467 | 0.97559 | 0.29190 | 0.32545 | 0.21891 | 0.47894 | 0.30725 |
| | 0.4365 | 0.4922 | 0.2014 | 0.5453 | 0.2961 | 0.0000 | 0.2735 | 0.0001 | 0.2253 | 0.1739 | 0.3679 | 0.0380 | 0.2007 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| TMACH | -0.14272 | -0.23415 | -0.15392 | -0.15240 | -0.14511 | 0.26467 | 1.00000 | 0.29416 | 0.20866 | -0.12001 | -0.16626 | -0.04759 | 0.58925 |
| | 0.5600 | 0.3346 | 0.5293 | 0.5334 | 0.5534 | 0.2735 | 0.0000 | 0.2215 | 0.3913 | 0.6246 | 0.4963 | 0.8466 | 0.0079 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| MACH6 | 0.13980 | 0.12995 | 0.26795 | 0.12578 | 0.17839 | 0.97559 | 0.29416 | 1.00000 | 0.26339 | 0.29517 | 0.18678 | 0.42367 | 0.29942 |
| | 0.5681 | 0.5960 | 0.2674 | 0.6079 | 0.4650 | 0.0001 | 0.2215 | 0.0000 | 0.2759 | 0.2199 | 0.4439 | 0.0707 | 0.2130 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| F1 | 0.89238 | 0.78322 | 0.88978 | 0.88673 | 0.79363 | 0.29190 | 0.20866 | 0.26339 | 1.00000 | 0.89562 | 0.90565 | 0.88699 | 0.82338 |
| | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.2253 | 0.3913 | 0.2759 | 0.0000 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| F2 | 0.92411 | 0.93881 | 0.96577 | 0.95682 | 0.84466 | 0.32545 | -0.12001 | 0.29517 | 0.89562 | 1.00000 | 0.98040 | 0.92584 | 0.68536 |
| | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.1739 | 0.6246 | 0.2199 | 0.0001 | 0.0000 | 0.0001 | 0.0001 | 0.0012 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| F3 | 0.97157 | 0.95335 | 0.98347 | 0.96942 | 0.88183 | 0.21891 | -0.16626 | 0.18678 | 0.90565 | 0.98040 | 1.00000 | 0.93528 | 0.66535 |
| | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.3679 | 0.4963 | 0.4439 | 0.0001 | 0.0001 | 0.0000 | 0.0001 | 0.0019 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| F4 | 0.95266 | 0.89529 | 0.95200 | 0.87958 | 0.89103 | 0.47894 | -0.04759 | 0.42367 | 0.88699 | 0.92584 | 0.93528 | 1.00000 | 0.69477 |
| | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0380 | 0.8466 | 0.0707 | 0.0001 | 0.0001 | 0.0001 | 0.0000 | 0.0010 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| F5 | 0.67297 | 0.64393 | 0.65489 | 0.65673 | 0.60045 | 0.30725 | 0.58925 | 0.29942 | 0.82338 | 0.68536 | 0.66535 | 0.69477 | 1.00000 |
| | 0.0016 | 0.0029 | 0.0023 | 0.0023 | 0.0066 | 0.2007 | 0.0079 | 0.2130 | 0.0001 | 0.0012 | [illegible] | [illegible] | 0.0000 |
| | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |

- LOGTB: Log Tail Blade Area
- LOGS: Log Shaft Horsepower
- LOGMD: Log Main Rotor Disc Area
- DISLO: Main Rotor Disc Loading

Other quantities which are linearly independent of these parameters can be expected to play the roles of second and third variable in the multiple regression analyses. However, it is possible to see more than one of these variables appear in a multiple regression if the two variables are largely independent of each other.

## 2.2 Summary of Best Correlates

The table provided below identifies those single parameters which best correlate with EPNL for the various operational modes.

| Level Flyover | | Takeoff | | Approach | |
|---|---|---|---|---|---|
| Parameter | $R^2$ | Parameter | $R^2$ | Parameter | $R^2$ |
| | | | | LOG TB | .889 |
| F2 | .774 | LOG TB | .910 | LOG W | .867 |
| LOG W | .769 | LOG W | .891 | LOG MD | .863 |
| LOG MD | .764 | F3 | .852 | F3 | .856 |
| F4 | .765 | LOG A | .850 | LOG A | .828 |
| F3 | .739 | LOG S | .826 | F2 | .821 |
| LOG TB | .727 | LOG MD | .826 | M DISC | .778 |
| LOG A | .727 | T BLADE | .819 | LOG S | .778 |
| | | | | AREA | .774 |
| | | | | T BLADE | .774 |

The most apparent trend one observes is the much higher correlation for takeoff and approach EPNL values as compared with level flyover EPNL. One plausible reason for this is that the level flyovers are conducted at a higher speed than the approaches or takeoffs. It is reasonable to assume that forces generating noise in higher speed operation are subject to more variant and anomolous aerodynamic influences.

Another observation is the decline of LOG TB to "fifth place" for the higher speed level flyover. This can be attributed to the diminished tail rotor counter-torque load as the speed increased. This occurs as unbalanced airframe slip stream forces tend to counter the main rotor torque.

### 2.3 Plots of Best Single Variable Regression

The three best single variable regression models are plotted in Figures 2.3.1 through 2.3.3 for takeoffs, in Figures 2.3.4 through 2.3.6 for approach, and in Figures 2.3.7 through 2.3.9 for level flyover. Each plot includes identification of helicopter type and the line of regression.

## 3.0 STEPWISE REGRESSION ANALYSES

This analysis investigates the improvement in prediction accuracy associated with adding a second and third variable to the single parameter regression equation. For the correlation coefficient to

improve the added variables (or steps) must be largely independent of previous step(s) but still related to the level of noise. Three-step models are presented below for takeoff, approach, and level flyover.

Approach

1 Step

EPNL = 10.2 log (TB) + 85.9

$R^2$ = .89

2 Step

EPNL = 7.1 log (TB) + .0007 (M DISC) + 86.9

$R^2$ = .93

3 Step

EPNL = 7.9 log (TB) + .005 (T SPEED) + .0006 (M DISC)

$R^2$ = .94

Level Flyover

1 Step

EPNL = 9.4 (F2) + 37.4

$R^2$ = .76

2 Step

EPNL = 10.4 log (MD) + 3.6 (F5) + 59.5

$R^2$ = .84

3 Step

EPNL = 10.7 log (MD) + 17 (MACH) + 3 (F5) + 44.9

$R^2$ = .85

Takeoff

1 Step

$$EPNL = 9.6 \log (TB) + 83.87$$

$$R^2 = .91$$

2 Step

$$EPNL = 9.55 \log (TB) - 7.3 (MACH)^6 + 86.1$$

$$R^2 = .93$$

3 Step

$$EPNL = 6.3 \log (TB) + 5.5 \log (MD) -9.6 (MACH)^6 + 71.97$$

$$R^2 = .95$$

The following table provides a summary of parameters and correlation coefficients associated with each step of the multiple regression analyses for the various operational modes:

Takeoff

| Step | $R^2$ | Parameter(s) |
|---|---|---|
| 1 | .91 | Log TB |
| 2 | .93 | Log TB, $(MACH)^6$ |
| 3 | .95 | Log TB, $(MACH)^6$, Log (MD) |

Approach

| Step | $R^2$ | Parameter(s) |
|---|---|---|
| 1 | .89 | Log TB |
| 2 | .93 | Log TB, M DISC |
| 3 | .94 | Log TB, M DISC, T SPEED |

Level Flyover

| Step | $R^2$ | Parameter(s) |
|---|---|---|
| 1 | .76 | F2 |
| 2 | .84 | F5, Log MD |
| 3 | .85 | Log MD, MACH, F5 |

## 4.0 DISCUSSION

The empirical noise prediction techniques presented above provide a means to estimate single event cumulative noise exposure for helicopters whose technology and operational characteristics are similar to the helicopters used in this analysis. The obvious advantage of the strictly empirical approach (using the single event cumulative energy metric EPNL) is the averaging out of source directionality, ground interference effects, anomolous air in-flow characteristics, and speed effects. All of these considerations pose significant difficulties in the theoretical approach. On the other hand, the theoretical approach can be more successful in predicting the change in noise level associated with a design change for a specific helicopter.

The parameters appearing (or not appearing) as significant correlates to noise in this study raise some interesting questions. For example, the strength of LOG TB was not anticipated nor is "Tail Blade Area" a particularly good acoustical design parameter. On the other hand, the main rotor advancing tip mach number to the sixth power (considered an important correlate to noise) appears as a weak correlate by itself, although it does strengthen the takeoff correlation in the multiple regression analysis. Interpretation of these results and discussion of application in predicting noise of new design helicopters or reducing levels of existent machines is left for subsequent study.

## TAKEOFF REGRESSION OF EPNL VERSUS LOGTB

EMPIRICAL NOISE PREDICTION ANALYSIS

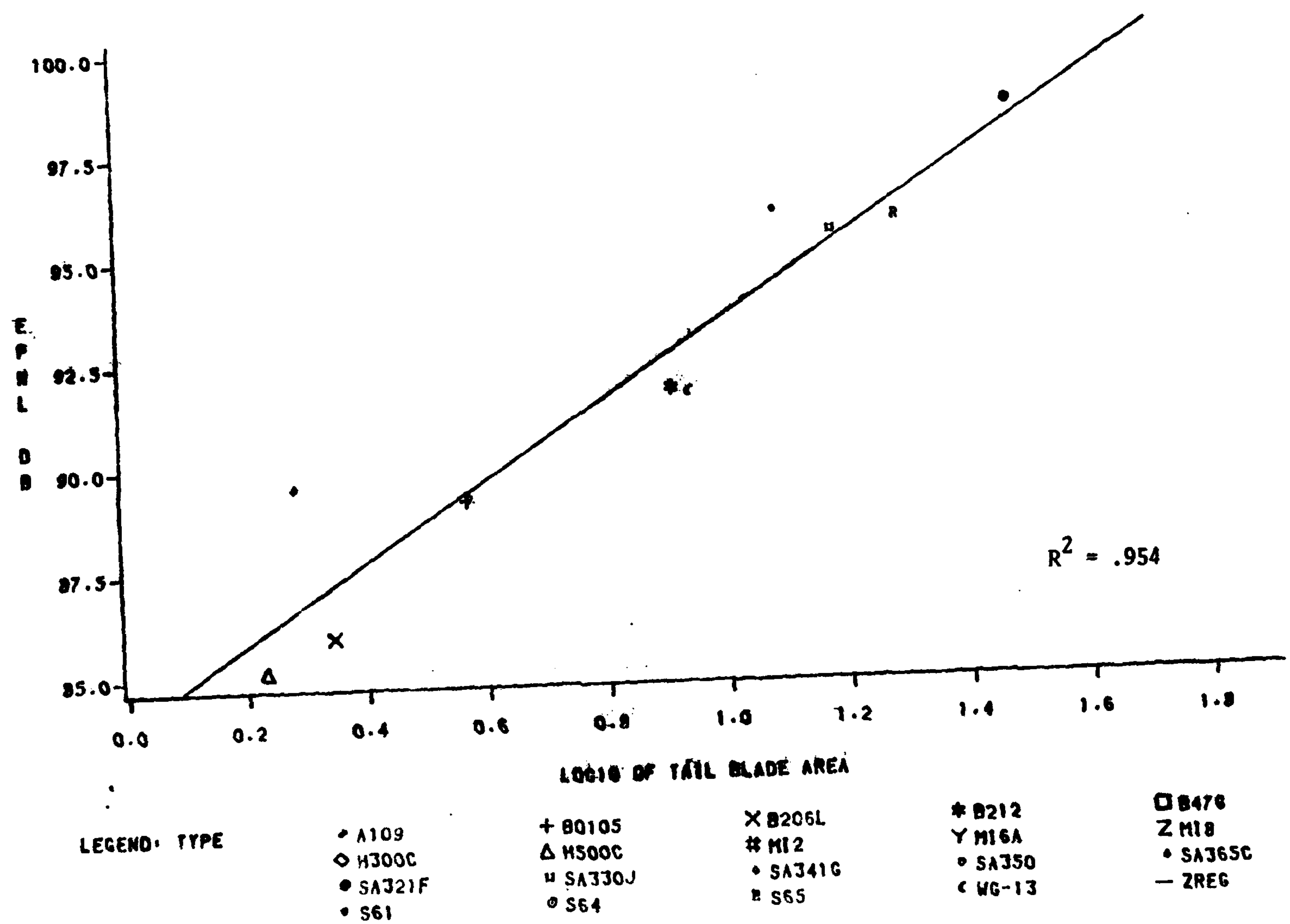
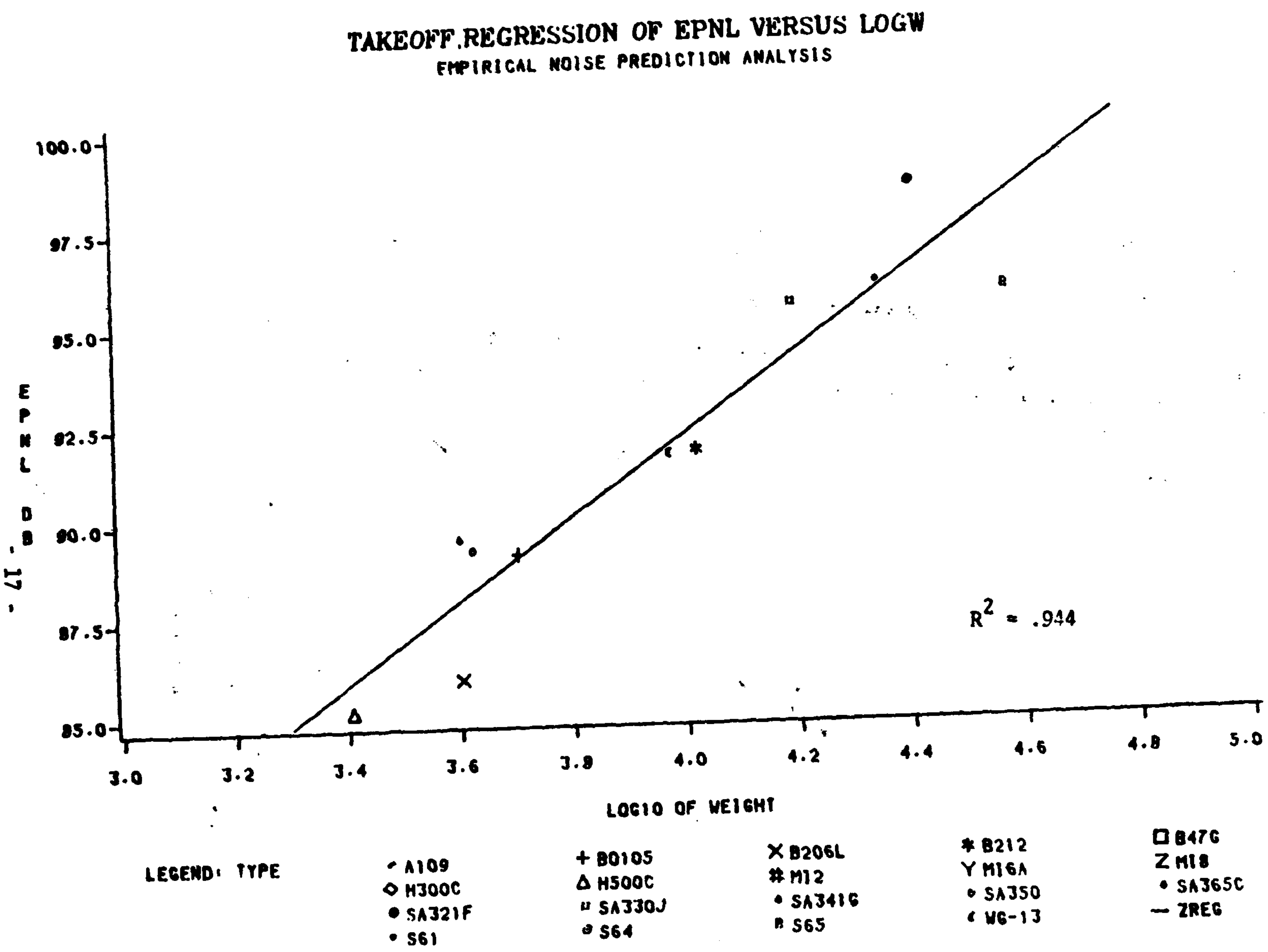



FIGURE 2.3.1

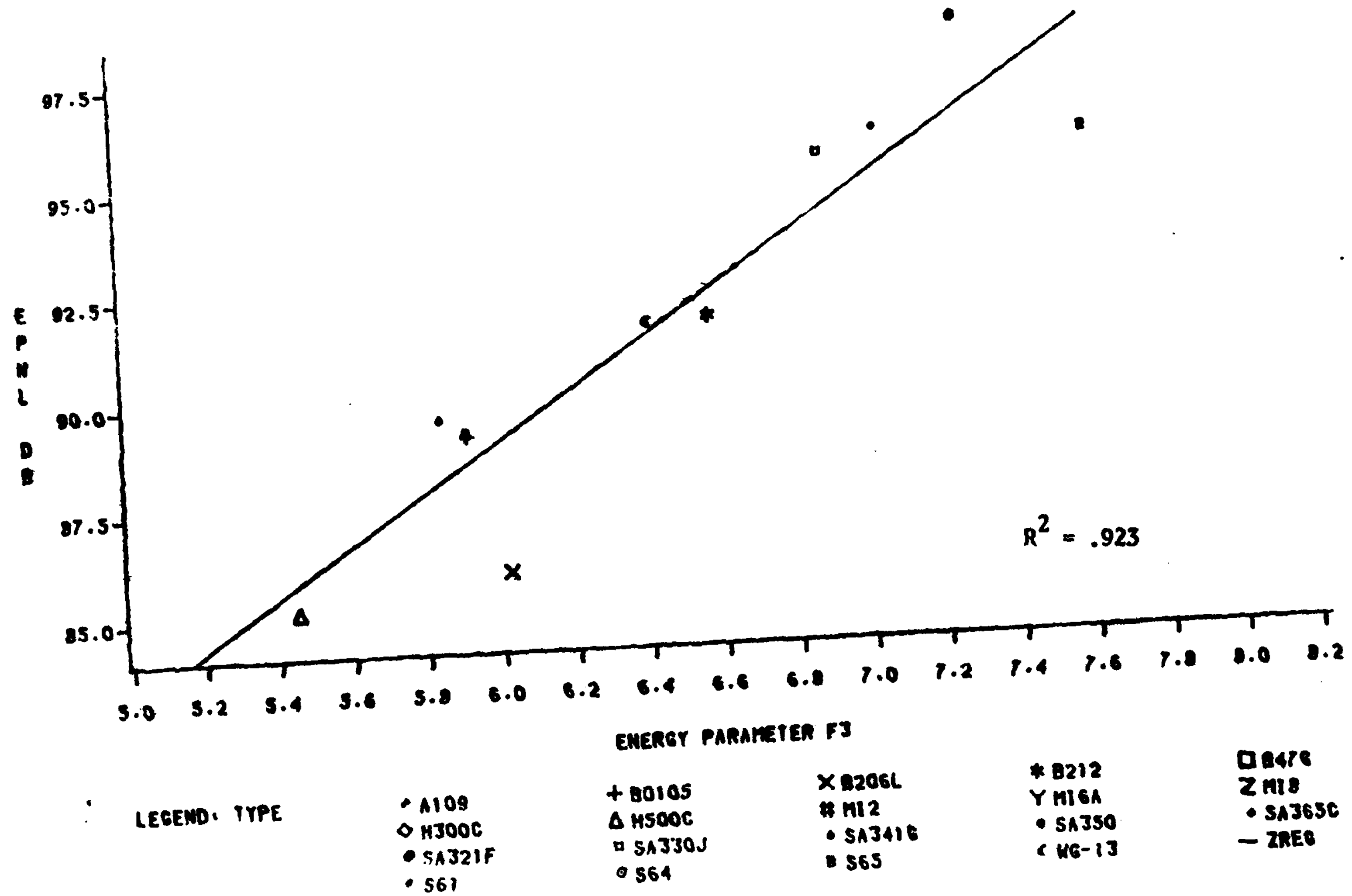


TAKEOFF REGRESSION OF EPNL VERSUS LOGW
EMPIRICAL NOISE PREDICTION ANALYSIS
100.0
97.5
95.0
92.5
90.0
87.5
85.0
EPNL DB
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
4.6
4.8
5.0
LOG10 OF WEIGHT
R2 = .944
LEGEND: TYPE
A109
H300C
SA321F
S61
BO105
H500C
SA330J
S64
B206L
M12
SA341G
S65
B212
M16A
SA350
WG-13
B47G
M18
SA365C
ZREG


FIGURE 2.3.2

## TAKEOFF REGRESSION OF EPNL VERSUS F3

EMPIRICAL NOISE PREDICTION ANALYSIS




F3=LOG10(SHP*MAIN DISC AREA/MACH)

FIGURE 2.3.3

LEVEL FLYOVER REGRESSION OF EPNL VERSUS F2

EMPIRICAL NOISE PREDICTION ANALYSIS

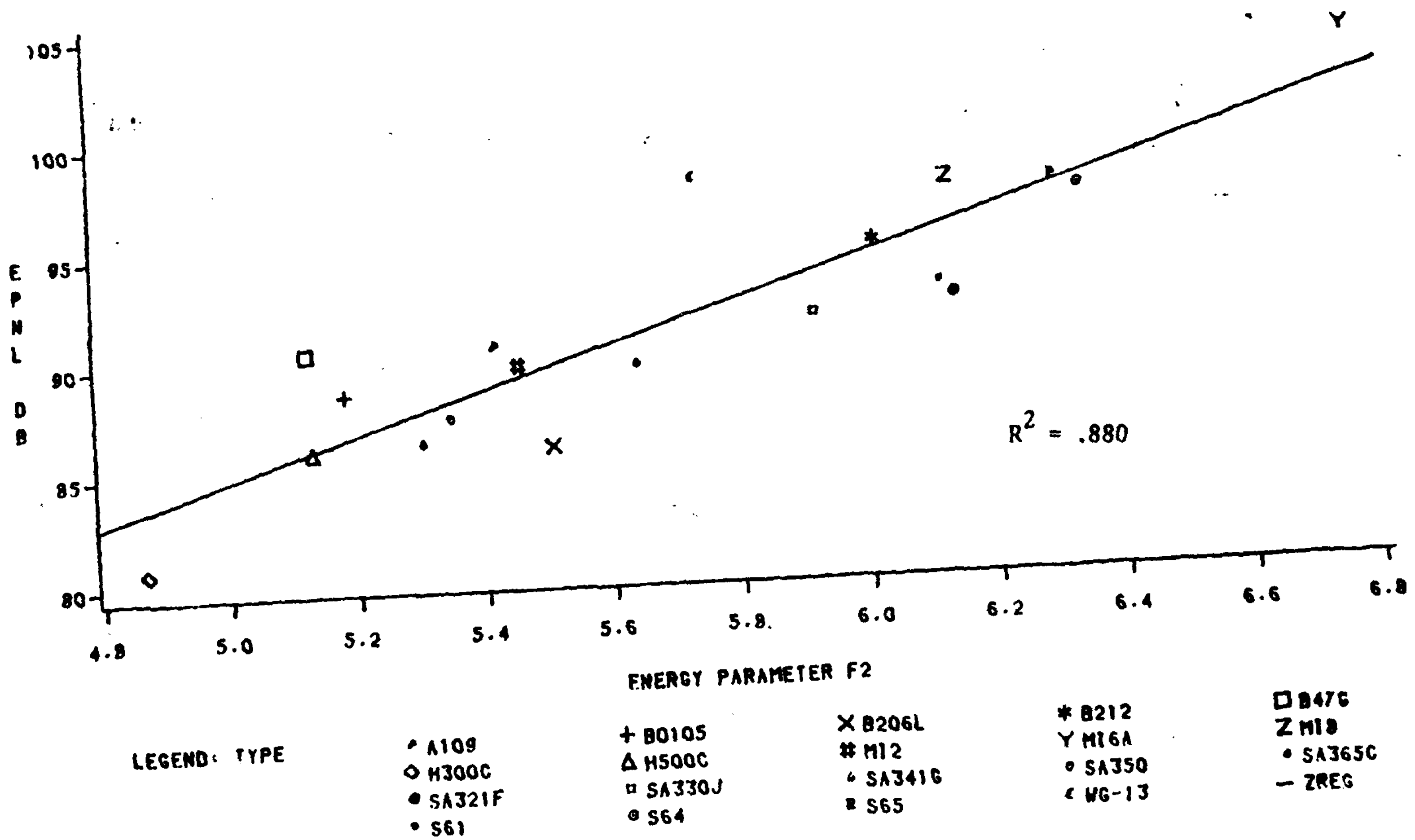



FIGURE 2.3.4

F2=LOG10((MACH*WEIGHT)**2/AREA)

LEVEL FLYOVER REGRESSION OF EPNL VERSUS LOGW

EMPIRICAL NOISE PREDICTION ANALYSIS

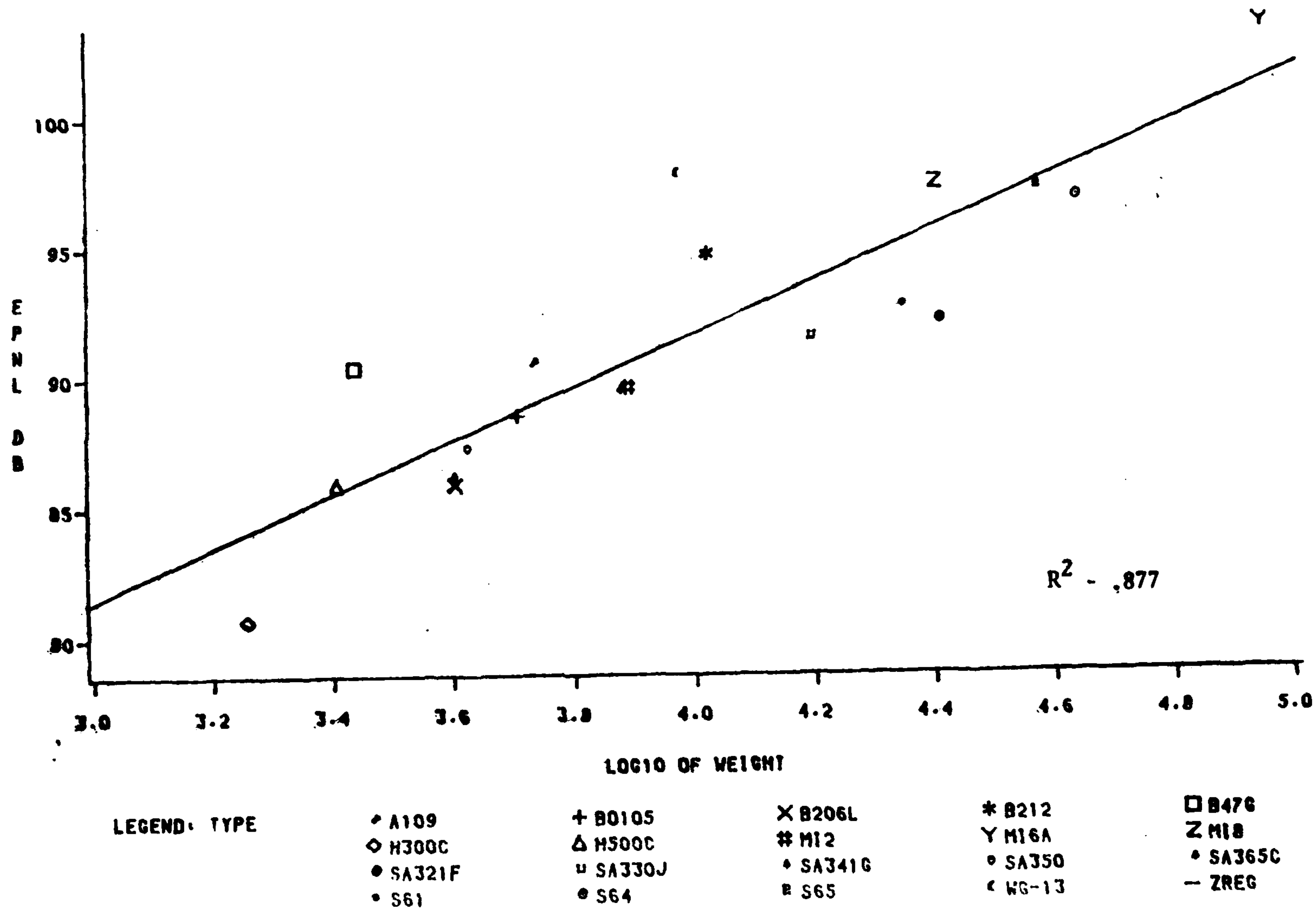
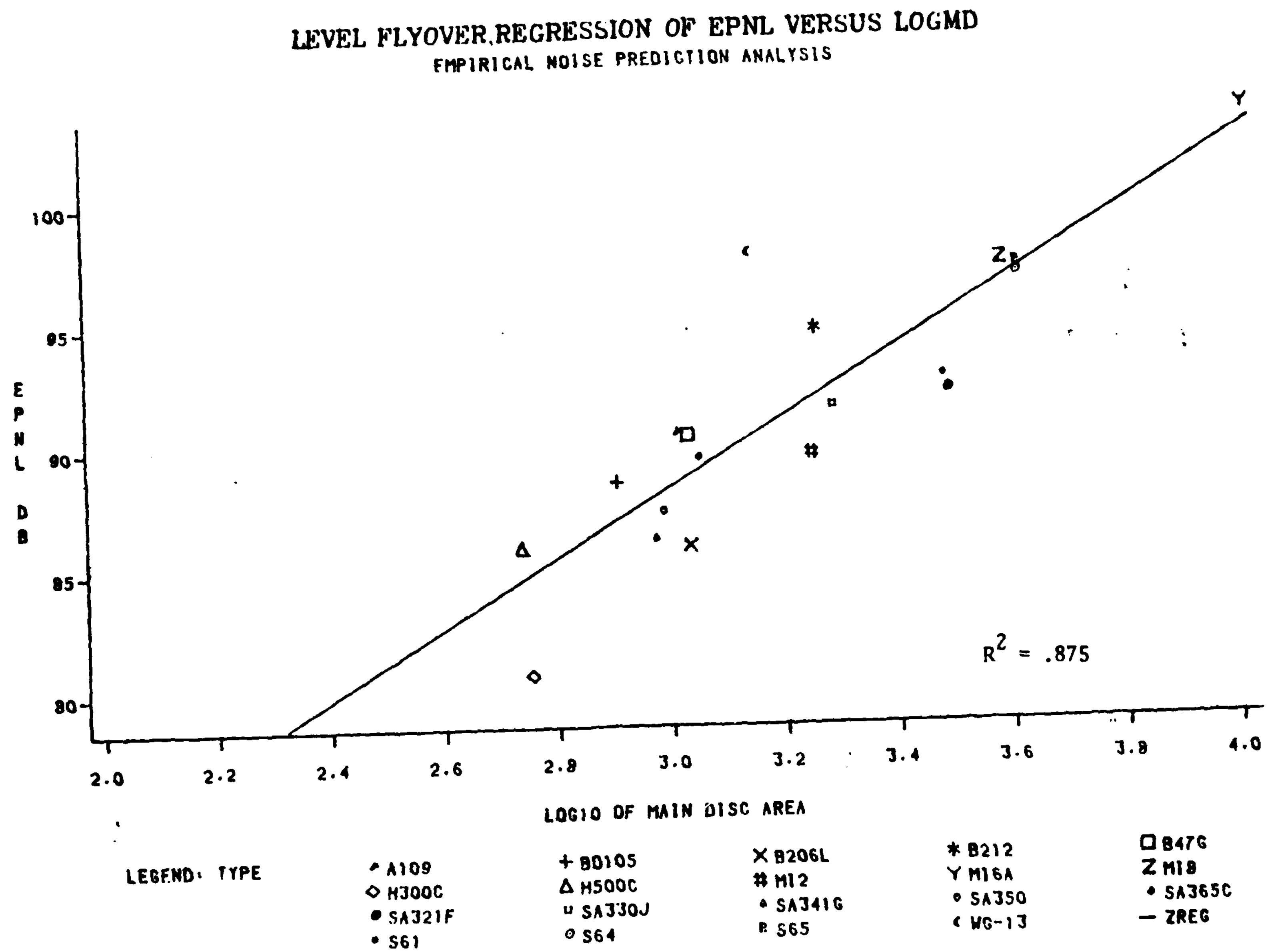



FIGURE 2.3.5



LEVEL FLYOVER.REGRESSION OF EPNL VERSUS LOGMD
EMPIRICAL NOISE PREDICTION ANALYSIS
EPNL DB
100
95
90
85
80
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
LOG10 OF MAIN DISC AREA
R2 = .875
LEGEND: TYPE
A109
H300C
SA321F
S61
BO105
H500C
SA330J
S64
B206L
M12
SA341G
S65
B212
M16A
SA350
WG-13
B47G
M18
SA365C
ZREG


FIGURE 2.3.6

APPROACH REGRESSION OF EPNL VERSUS LOGTB

EMPIRICAL NOISE PREDICTION ANALYSIS

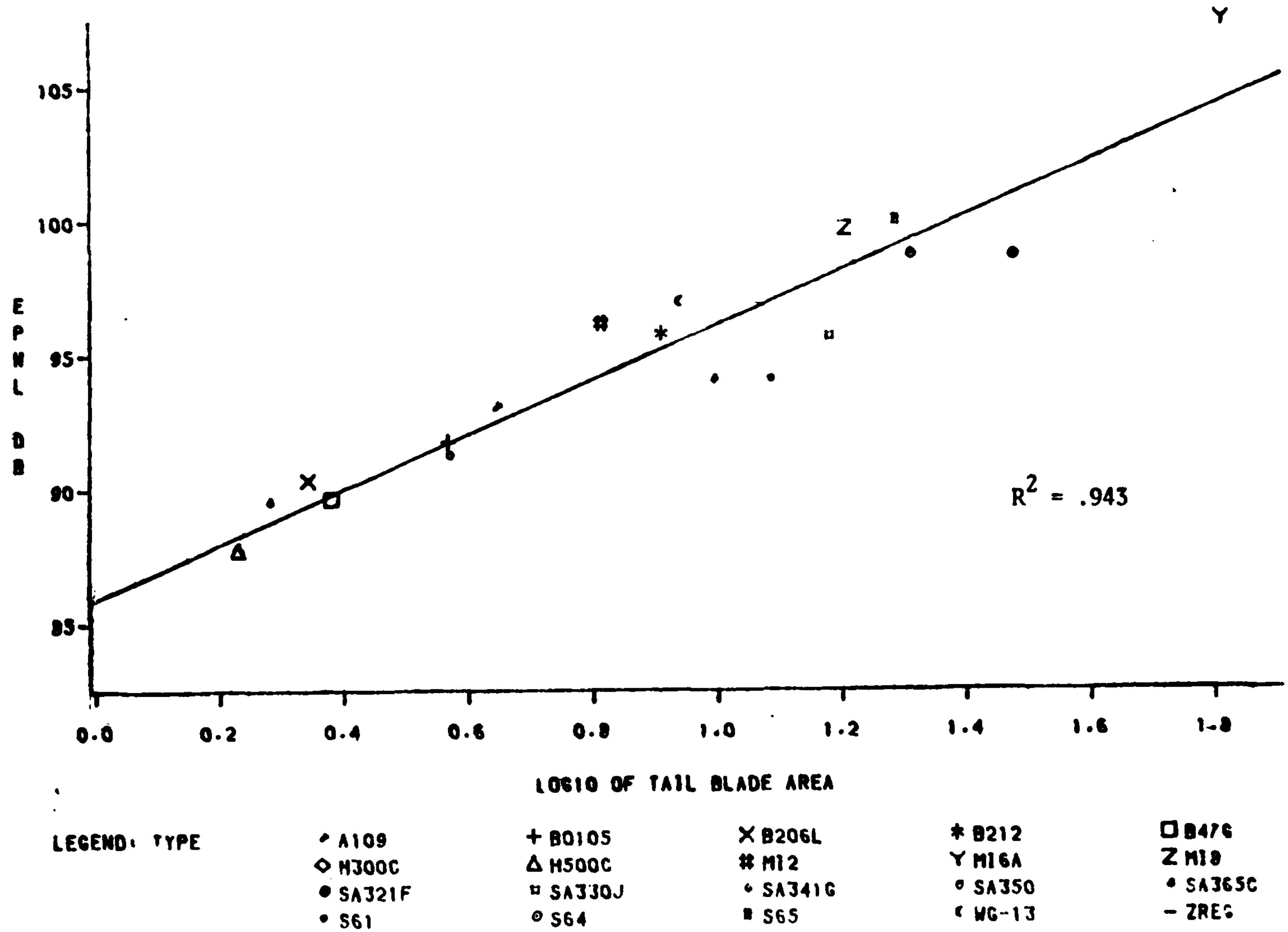



FIGURE 2.3.7

APPROACH REGRESSION OF EPNL VERSUS LOGW
EMPIRICAL NOISE PREDICTION ANALYSIS

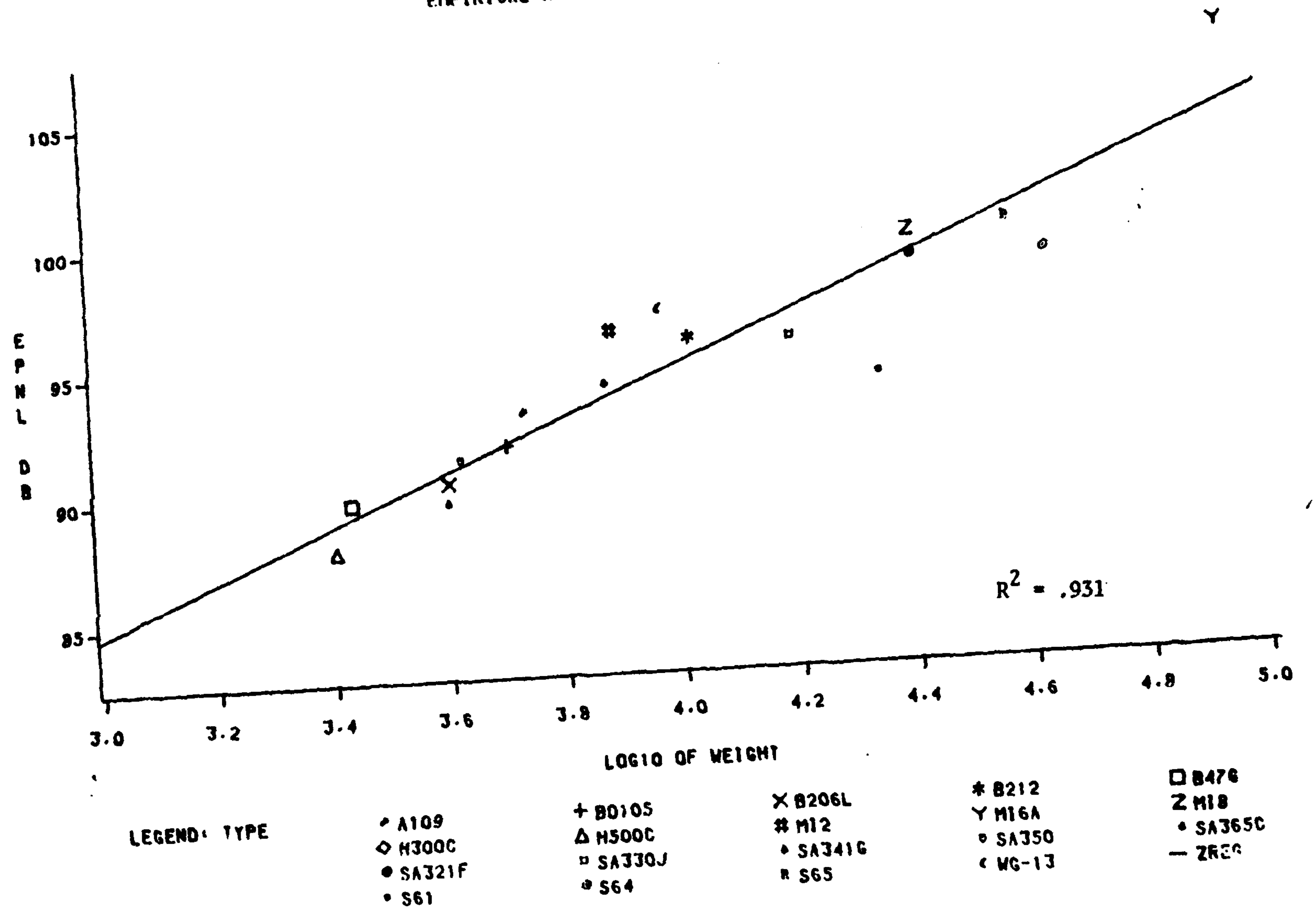



FIGURE 2.3.8

## APPROACH REGRESSION OF EPNL VERSUS LOGMD

EMPIRICAL NOISE PREDICTION ANALYSIS

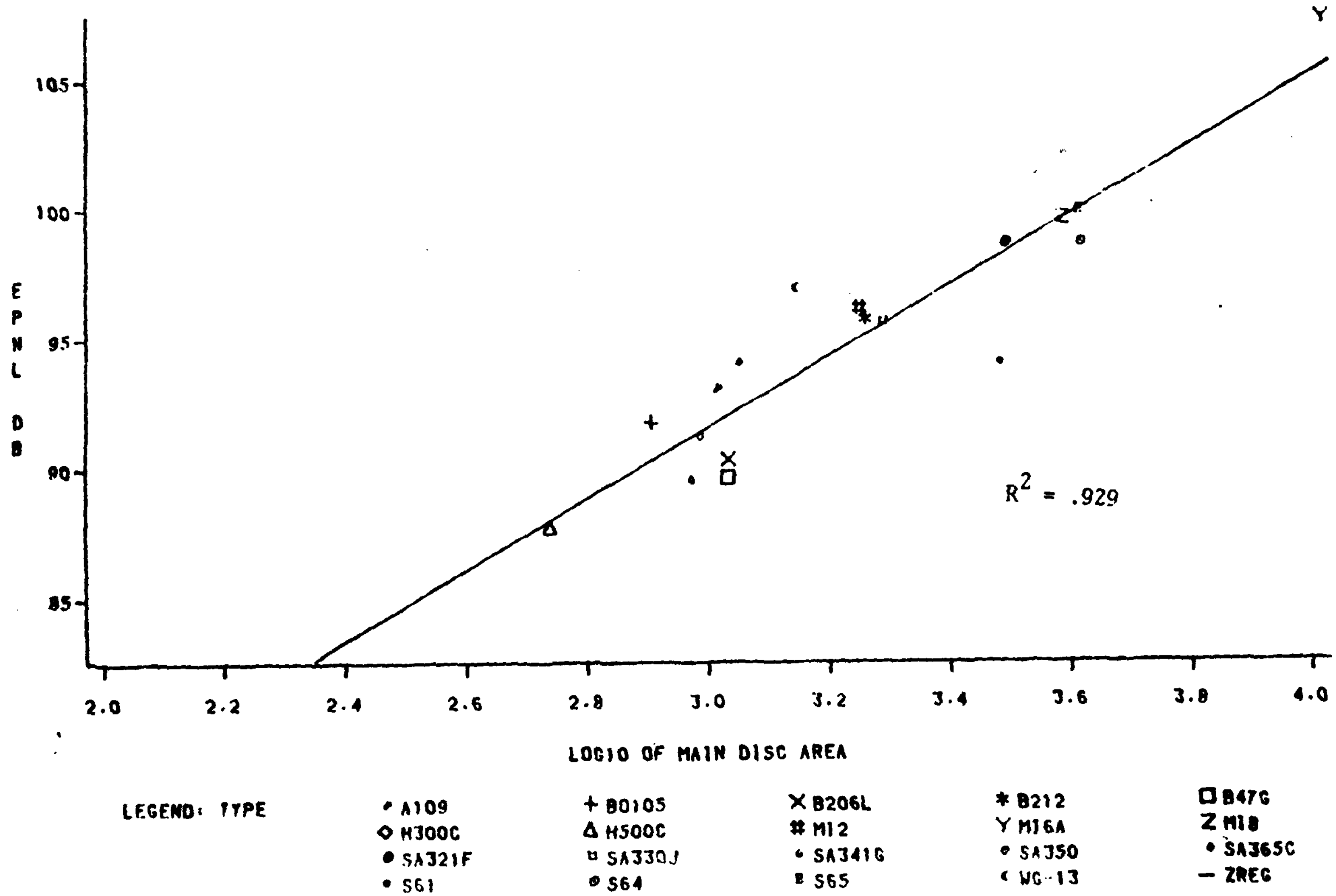



FIGURE 2.3.9

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